2014

Waushara County Lakes Study
Lake Napowan

Final Report
to Waushara County and
Wisconsin Department of Natural Resources

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ACKNOWLEDGMENTS

We are grateful to many people for supporting this project by providing insight, enthusiasm, and funding. We would like to recognize our project partners:

Waushara County Watershed Lakes Council

Waushara County Staff and Citizens

Wisconsin Department of Natural Resources Professionals, Mark Sessing and Ted Johnson

Wisconsin Department of Natural Resources Lake Protection Grant Program

Dr. Samantha Kaplan and Dr. Paul McGinley

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LAKE NAPOWAN STUDY RESULTS

WAUSHARA COUNTY LAKES STUDY BACKGROUND

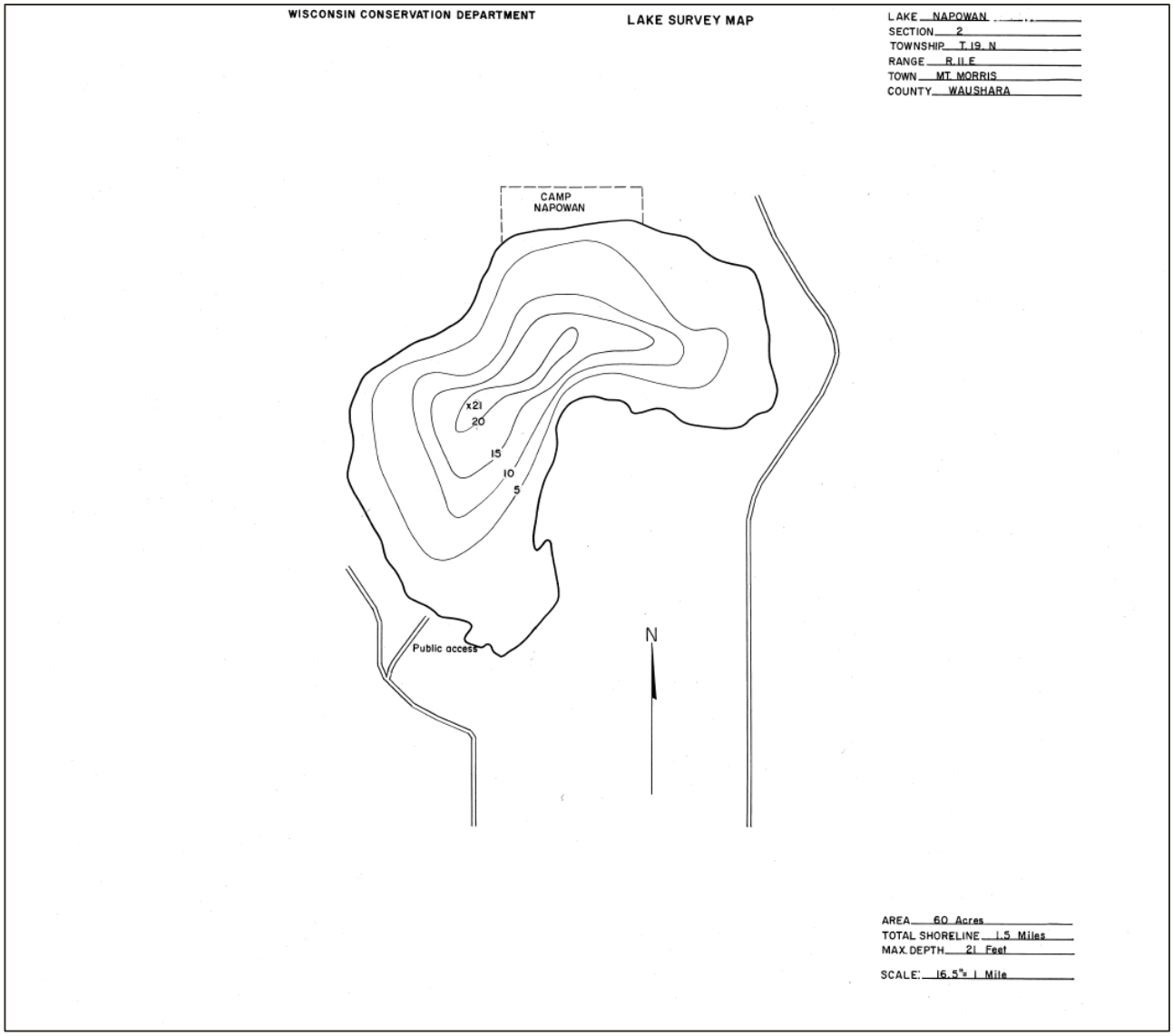
Lakes and rivers contribute to the way of life in Waushara County. Local residents and visitors alike enjoy fishing, swimming, boating, wildlife viewing, and the peaceful nature of the lakes. Healthy lakes add value to our communities. They provide places to relax and recreate, and they can stimulate tourism. Like other infrastructure in our communities, lakes require attention and good management practices to remain healthy in our developing watersheds.

Thirty-three lakes in Waushara County were selected for this study. The study focused on learning about the lakes' water quality, aquatic plant communities, shoreland habitats, watersheds and histories in order to help people make informed lake management decisions. This report summarizes data collected for Lake Napowan between fall 2010 and fall 2012.

ABOUT LAKE NAPOWAN

To understand a lake and its potential for water quality, fish and wildlife, and recreational opportunities, we need to understand its physical characteristics and setting within the surrounding landscape. The lake is located in the township of Mt. Morris, southeast of Wild Rose, and south of County Road A, with one public boat launch located on its southwest side. Lake Napowan is a 52-acre seepage lake with surface runoff and groundwater contributing most of its water. The official maximum depth in Lake Napowan is 21 feet; the lakebed has a gradual slope (Figure 1). Lake Napowan has an estimated water residence time of 9.6 months. The residence time helps determine the potential effects of contaminants entering the lake and is related to the duration that pollutants may stay in the lake. Lake Napowan's bottom sediments are mostly sand with some muck.

FIGURE 1. CONTOUR MAP OF THE LAKE NAPOWAN LAKEBED.



WHERE IS THE WATER COMING FROM? - WATERSHEDS AND LAND USE

The water quality in Lake Napowan is a reflection of the land that drains to it. The water quality, the amount of algae, aquatic plants, the fishery and other animals in the lake are all affected by natural and man-made characteristics. Natural characteristics that affect a lake include the amount of land that drains to the lake, the hilliness of the landscape, types of soil, extent of wetlands, and the type of lake. Within the lake's watershed, alterations to the landscape, the types of land use, and the land management practices are examples of how people may affect the lake.

It is important to understand where Lake Napowan's water originates in order to understand the lake's health. During snowmelt or a rainstorm, water moves across the surface of the landscape (runoff) towards lower elevations such as lakes, streams, and wetlands. The land area that contributes runoff to Lake Napowan is called a surface watershed. Groundwater also feeds Lake Napowan; its land area may be slightly different than the surface watershed. The surface watershed is shown in Figure 2.

The capacity of the landscape to shed or hold water and contribute or filter particles ultimately determines the amount of erosion that may occur, the amount of groundwater feeding a lake, and ultimately, the lake's water quality and quantity. Essentially, landscapes with a greater capacity to hold water during rain events and snowmelt help to slow the delivery of the water to the lake. Minimizing excess runoff is desirable because it allows more water to recharge the groundwater, which feeds the lake year-round - even during dry periods or when the lake is covered with ice.

Land use and land management practices within a lake's watershed can affect both its water quantity and quality. While forests and grasslands allow a fair amount of precipitation to soak into the ground, resulting in more groundwater and better water quality, other types of land uses may result in increased runoff and less groundwater recharge, and may be sources of pollutants that can impact the lake and its inhabitants. Areas of land with exposed soil can produce soil erosion. Soil entering the lake can make the water cloudy and cover fish spawning beds. Soil also contains nutrients that increase the growth of algae and aquatic plants. Development on the land often results in changes to natural drainage patterns, alterations to vegetation on the landscape, and may be a source of pollutants. Impervious (hard) surfaces such as roads, rooftops, and compacted soil prevent rainfall from soaking into the ground, which may result in more runoff that carries pollutants to the lake. Wastewater, animal waste, and fertilizers used on lawns, gardens, and crops can contribute nutrients that can enhance the growth of algae and aquatic plants in our lakes.

A variety of land management practices can be put in place to help reduce impacts to our lakes. Some practices are designed to reduce runoff. These include protecting/restoring wetlands, installing rain gardens, swales, rain barrels, and routing drainage from pavement and roofs away from the lake. Some practices are used to help reduce nutrients from moving across the landscape towards the lake. Examples include manure management practices, eliminating/reducing the use of fertilizers, increasing the distance between the lake and a septic drainfield, protecting/restoring native vegetation in the shoreland, and using erosion control practices. Waushara County staff and other professionals can work with landowners to determine which practices are best suited to a particular property.

LAKE NAPOWAN SURFACE WATERSHED

The surface watershed for Lake Napowan and Big Hills Lake is approximately 1,239 acres (Figure 2). The lakes are close in proximity and are hydologically connected. The dominant types of land use in the watershed are forests (33%), developed land (32%), and agriculture (24%). The land closest to the lake often has the greatest impact on water quality and habitat; Lake Napowan's shoreland is surrounded primarily by forests, wetlands, and developed land.

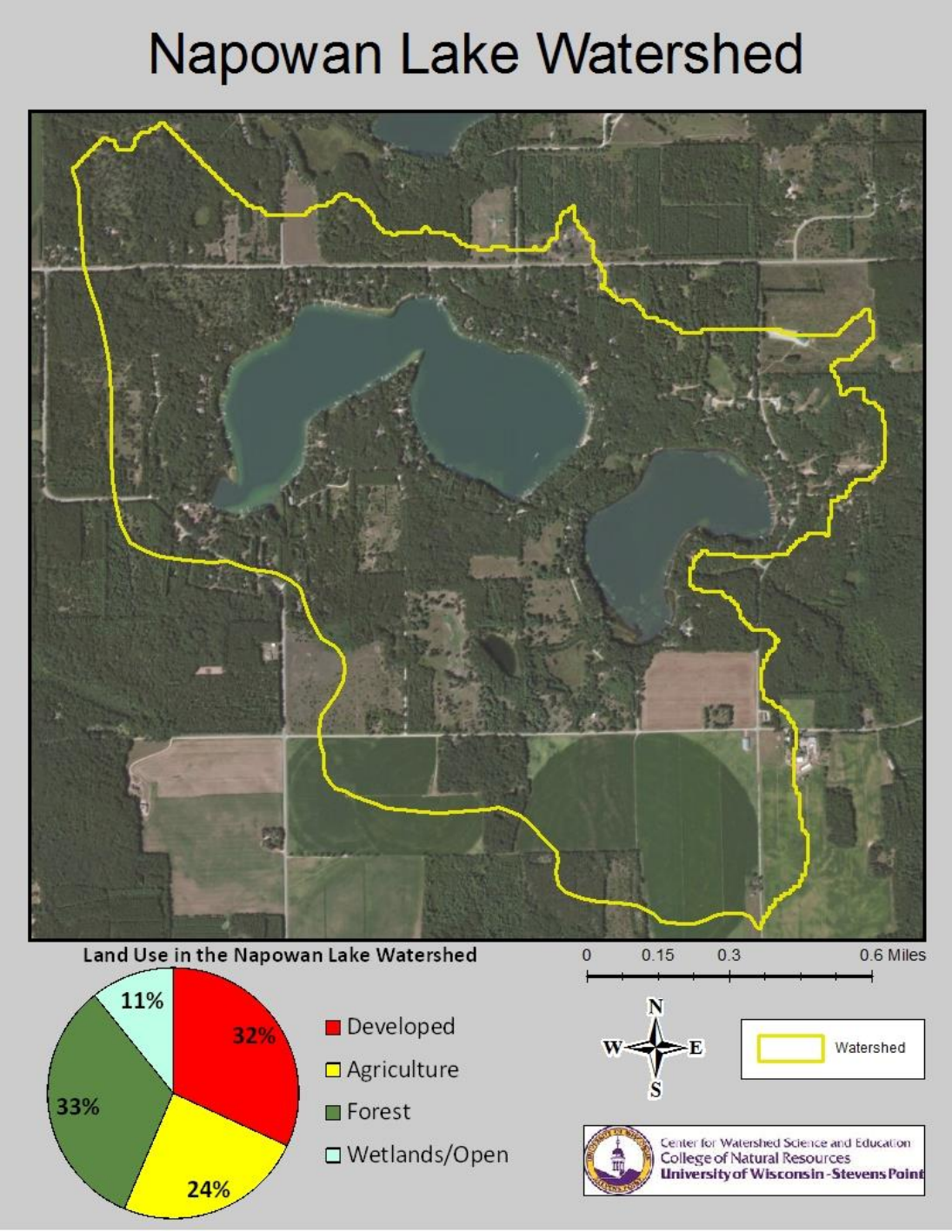


FIGURE 2. LAND USE IN THE LAKE NAPOWAN SURFACE WATERSHED.

The more the lake's water interacts with groundwater, the more influence the geology has on the lake. The length of time water remains below ground affects the temperature and chemistry of the groundwater. Groundwater temperature is near constant year round; during the summer, groundwater feeding Lake Napowan will help keep the lake water cooler and during the winter may keep parts of the lake ice-free.

Groundwater flows below ground from higher to lower elevations, discharging into wetlands, streams, and lakes. The groundwater feeding the lakes in Waushara County originates nearby. The black arrows in Figure 3 indicate the general direction of groundwater flow. Much of the groundwater enters Lake Napowan from the west.

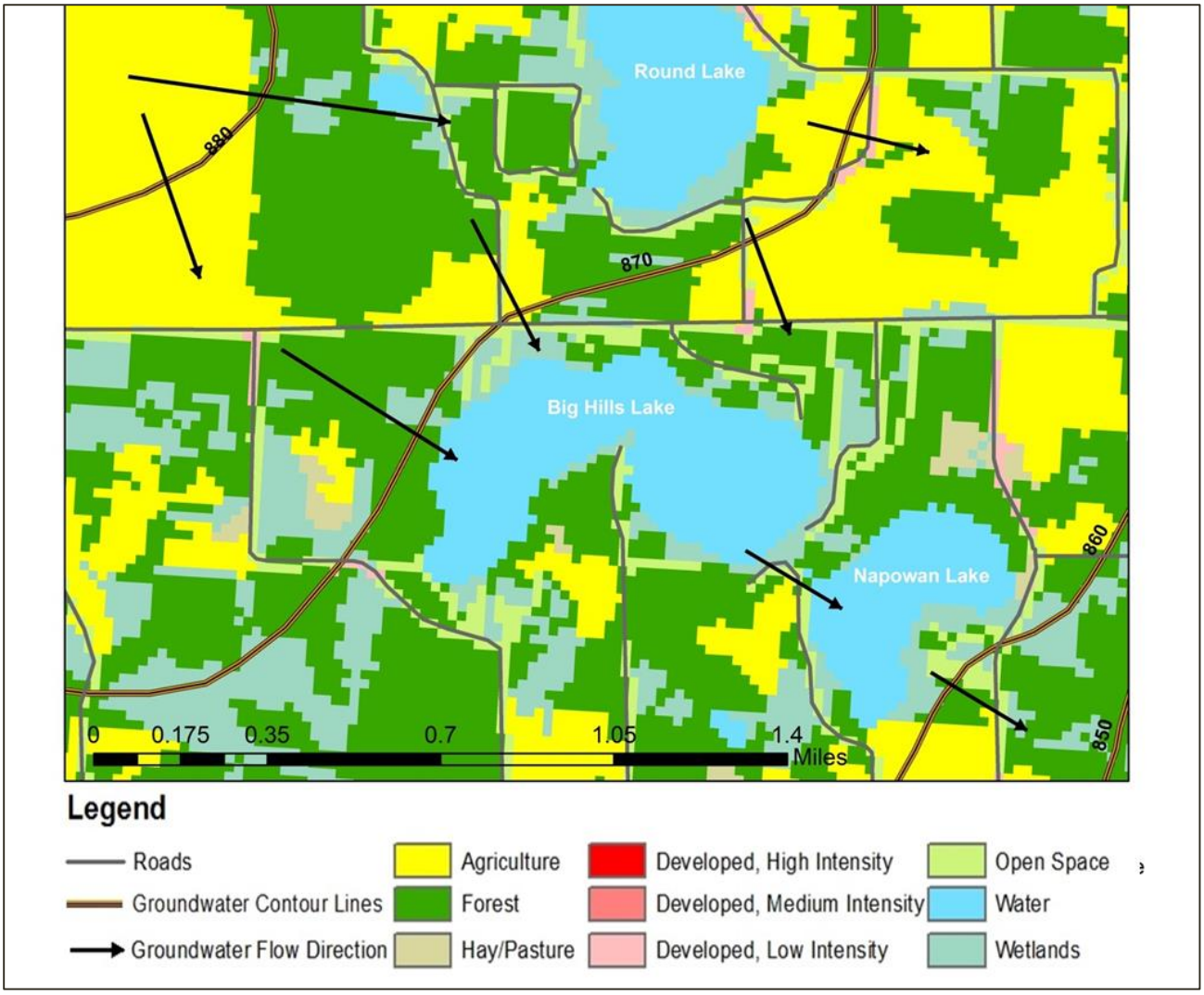
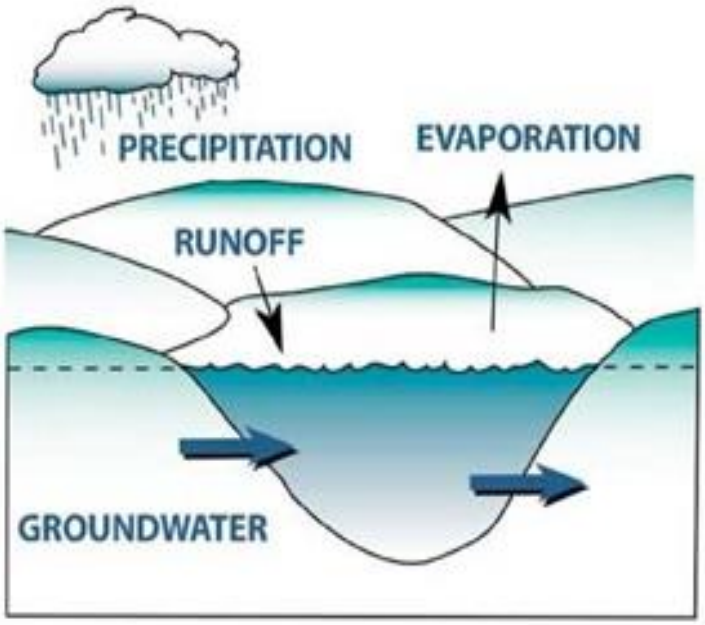


FIGURE 3. GROUNDWATER FLOW DIRECTION NEAR LAKE NAPOWAN.

WATER QUALITY

Lake water quality is a result of many factors including the underlying geology, the climate, and land management practices. Assessing lake water quality allows us to evaluate current lake health and changes from the past. During this study, water quality in Lake Napowan was assessed by measuring different characteristics including temperature, dissolved oxygen, water clarity, and water chemistry.

The source of a lake's water supply is important in determining its water quality and choosing management practices to preserve or influence that quality. Lake Napowan receives its water primarily via groundwater with lesser inputs from direct runoff and precipitation (Figure 4). Lake Napowan is classified as a seepage lake.



The geologic composition that lies beneath a lake has the ability to influence the pH, minerals, and other properties in a lake. Seepage lakes like Lake Napowan have higher concentrations of minerals such as calcium and magnesium which dissolve from surrounding soil and rock into the groundwater as it travels toward the lake, making the water hard. The average hardness for Lake Napowan during the 2010-2012 sampling period was 119 mg/L, which is considered moderately hard (Table 1). Hard water provides the calcium for building bones and shells of the animals in the lake. The average alkalinity was 119 mg/L; higher alkalinity in inland lakes can support higher species productivity. Hardness and alkalinity also play a role in the type of aquatic plants that are found in a lake (Shaw et al., 2000).

FIGURE 4. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN A SEEPAGE LAKE.

TABLE 1. MINERALS AND PHYSICAL MEASUREMENTS IN LAKE NAPOWAN, 2010-2012.

Lake Napowan	Alkalinity (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Manganese (mg/L)	Total Hardness (mg/L as $CaCO_3$)	Color (SU)	Turbidity (NTU)
Average Value	119	24.3	14.7	30	119	12.3	2.0

Chloride concentrations, and to a lesser degree sodium and potassium concentrations, are commonly used as indicators of how a lake is being impacted by human activity. The presence of these compounds where they do not naturally occur indicates sources of water contaminants.

Lake Napowan had slightly elevated chloride and sodium concentrations and a low average sodium concentration over the monitoring period (Table 2). These concentrations are not harmful to aquatic organisms, but indicate that pollutants are entering the lake. Chloride and sodium sources include animal

waste, septic systems, fertilizer, and road-salting chemicals. Atrazine, an herbicide commonly used on corn, was found in low concentrations in Lake Napowan (0.10 µg/L DACT); however, some toxicity studies have indicated that reproductive system abnormalities can occur in frogs at these levels (Hayes et al., 2003). The presence of this chemical suggests that agricultural activities in the surrounding landscape may be impacting the lake.

TABLE 2. LAKE NAPOWAN AVERAGE WATER CHEMISTRY, 2010-2012.

Lake Napowan	Average Value (mg/L)			Reference Value (mg/L)		
	Low	Medium	High	Low	Medium	High
Potassium	0.60			<.75	0.75-1.5	>1.5
Chloride		3.1		<3	3.0-10.0	>10
Sodium		2.3		<2	2.0-4.0	>4

Dissolved oxygen is an important measure in Lake Napowan because a majority of organisms in the water depend on oxygen to survive. Oxygen is dissolved into the water from contact with the air, which is increased by wind and wave action. Algae and aquatic plants also produce oxygen when sunlight enters the water, but the decomposition of dead plants and algae reduces oxygen in the lake.

In a lake, the water temperature changes throughout the year and may vary with depth. During winter and summer when lakes stratify (layer), the amount of dissolved oxygen is often lower towards the bottom of the lake. Dissolved oxygen concentrations below 5 mg/L can stress some species of cold water fish and over time can reduce the amount of available habitat for sensitive cold water species of fish and other aquatic organisms.

Water temperature and dissolved oxygen were measured in Lake Napowan from top to bottom at the time of each sample collection in the 2010-2012 study. Some weak layering by temperature develops in Lake Napowan between June and September with temperatures in the upper 10-12 feet of water ranging between 22C (72°F) and 28C (82°F) before dropping to around 10C (50°F) near the bottom (Figure 5). The lake water was mixed from top to bottom during fall overturn in 2010 and 2011, and spring overturn in 2011 and 2012, which can be seen in the graph as nearly vertical lines.

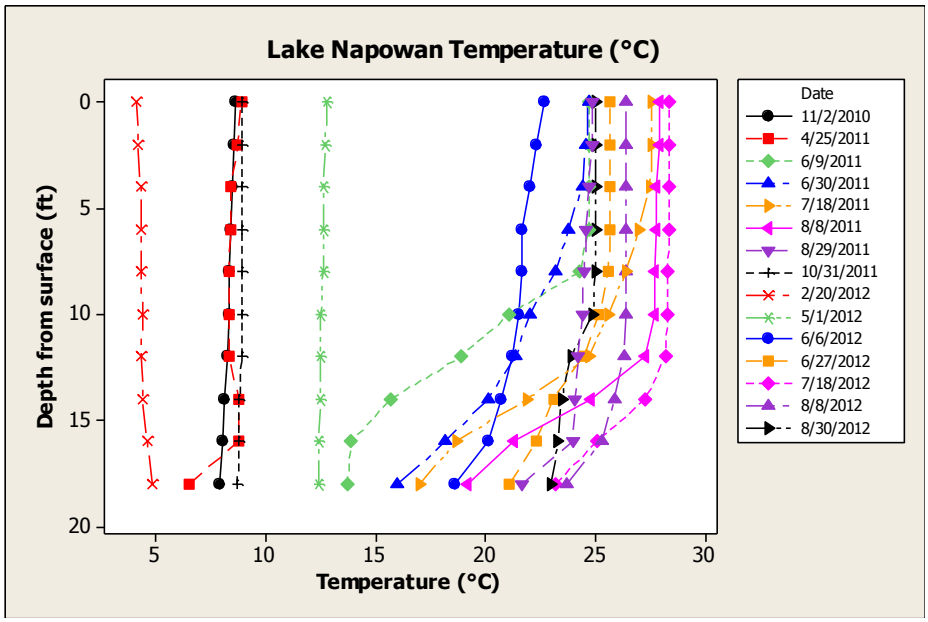


FIGURE 5. TEMPERATURE PROFILES IN LAKE NAPOWAN, 2010-2012.

During the study, dissolved oxygen was plentiful throughout most of the lake, with the exception of the measurement made in February 2012 when dissolved oxygen concentrations fell below 5 mg/L throughout the water column (Figure 6). During the summer, dissolved oxygen in Lake Napowan was higher in the shallow water and dropped off with depth. The lower concentrations towards the bottom are typical and are due to the consumption of oxygen during the decomposition of materials at the bottom of the lake.

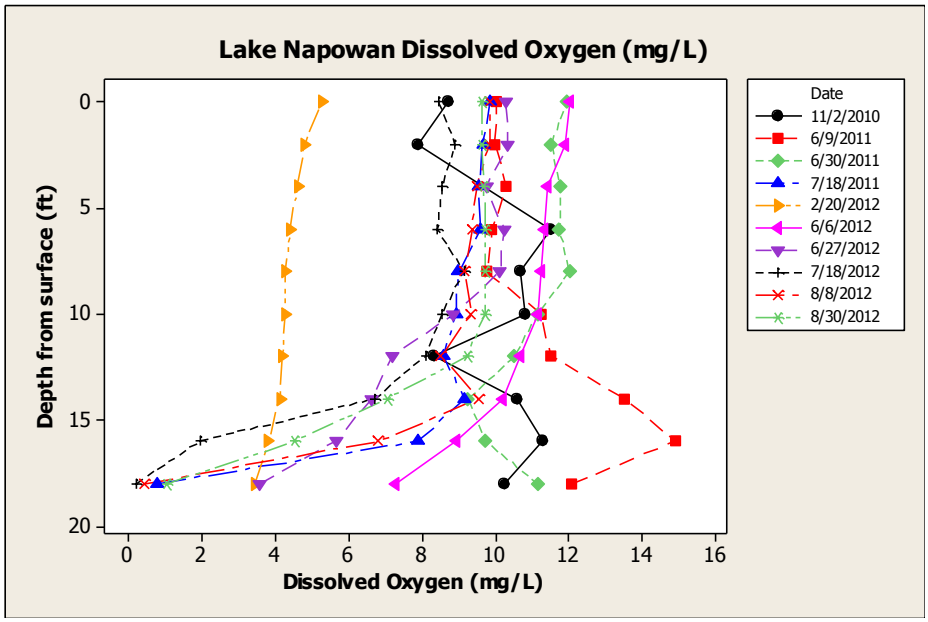


FIGURE 6. DISSOLVED OXYGEN PROFILES IN LAKE NAPOWAN, 2010-2012.

Water clarity is a measure of the depth that light can penetrate into the water. It is an aesthetic measure and is also related to the depth that rooted aquatic plants can grow. Water clarity is affected by water color, turbidity (suspended sediment), and algae, so it is normal for water clarity to change throughout the year and from year to year.

In Lake Napowan, color (staining) was relatively low (Table 1), indicating that the variability in transparency throughout the year is primarily due to fluctuating algal abundance and re-suspended sediment following storms and/or periods with heavy boating activity.

The water clarity measured in Lake Napowan during the study was considered good. For Lake Napowan, water clarity ranged from 6.5 feet to 19 feet (Figure 7).

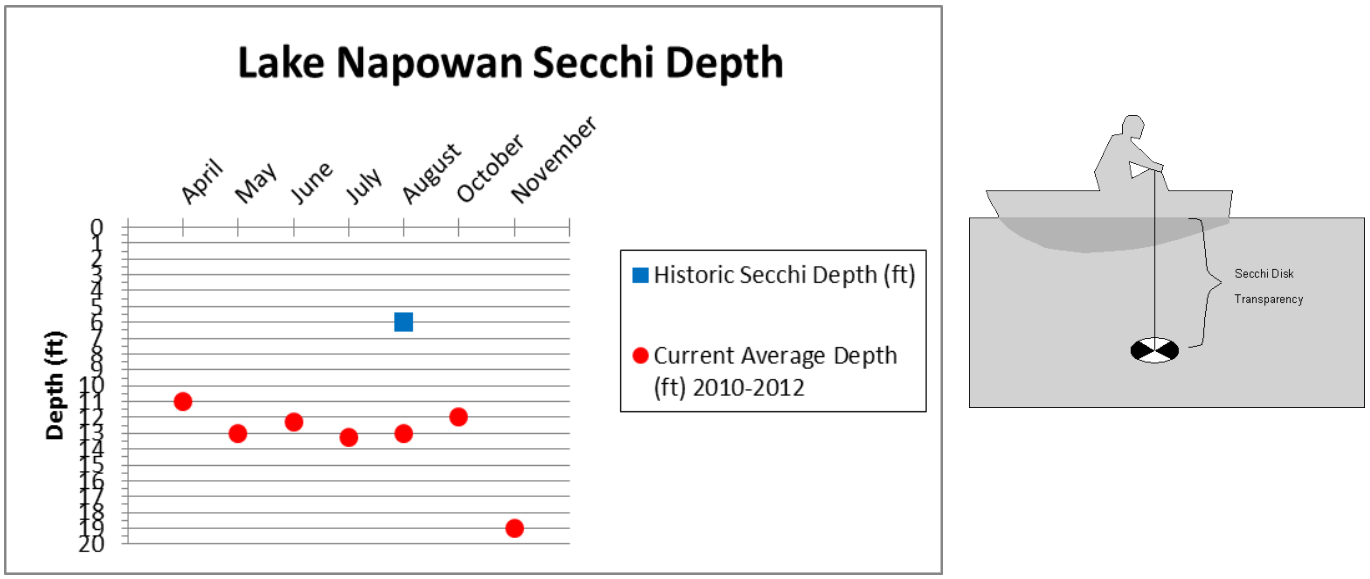


FIGURE 7. WATER CLARITY IN LAKE NAPOWAN, 2010-2012 AND HISTORIC.

Nutrients (phosphorus and nitrogen) are used by algae and aquatic plants for growth. Phosphorus is present naturally throughout the watershed in soil, plants, animals, and wetlands. Additional sources from human activities may include soil erosion, animal waste, fertilizers, and septic systems.

It is most common for phosphorus to move from the land to the water through surface runoff, but it can also travel to the lake in groundwater. Once in a lake, a portion of the phosphorus becomes part of the aquatic system in the forms of plant tissue, animal tissue, and sediment. Once in the lake, the phosphorus can continue to cycle within the lake for many years.

During the study, total phosphorus concentrations for Lake Napowan ranged from a high of 31 ug/L in April 2011 to a low of 12 ug/L in August 2012 (Table 3). The summer median total phosphorus was 18.5 ug/L and 16 ug/L in 2011 and 2012, respectively. This is below Wisconsin's phosphorus standard for a shallow seepage lake such as Lake Napowan of 40 ug/L, but above the proposed flag value of 15 ug/L.

Chlorophyll *a* is a measurement of algae in the water. Chlorophyll *a* concentrations in Lake Napowan varied throughout the summer monitoring period, ranging from a high of 6 ug/L in August 2011 to a low of 1 ug/L in early June 2011 and late August 2012. The average for the monitoring period was 2.6 ug/L; these concentrations are considered low.

TABLE 3. SEASONAL SUMMARY OF NUTRIENT CONCENTRATIONS IN LAKE NAPOWAN, 2010-2012.

Napowan Lake	Inorganic Nitrogen (mg/L)			Organic Nitrogen (mg/L)			Total Nitrogen (mg/L)			Soluble Reactive Phosphorus (ug/L)			Total Phosphorus (ug/L)		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Fall	0.02	0.02	0.02	0.71	0.71	0.71	0.79	0.79	0.79	7	7	7	19	19	19
Spring	0.05	0.08	0.11	0.68	0.68	0.68	0.84	0.84	0.84	5	8	11	25	28	31
Summer													12	18	22
Winter	0.05	0.06	0.06	0.60	0.60	0.60	0.98	0.98	0.98	1	1	1	16	16	16

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Lake Napowan. Land use in the surface watershed was evaluated and used to populate the Wisconsin Lakes Modeling Suite (WILMS) model. In general, each type of land use contributes different amounts of phosphorus in runoff and through groundwater. The types of land management practices that are used and the distance from the lake also affect the contributions to the lake from a parcel of land. Based on modeling results, agriculture and developed land had the greatest percentages of phosphorus contributions from the watershed to Lake Napowan (Figure 8). The phosphorus contributions by land use category, called phosphorus export coefficients, are shown in Table 4. The phosphorus export coefficients have been obtained from studies throughout Wisconsin (Panuska and Lillie, 1995).

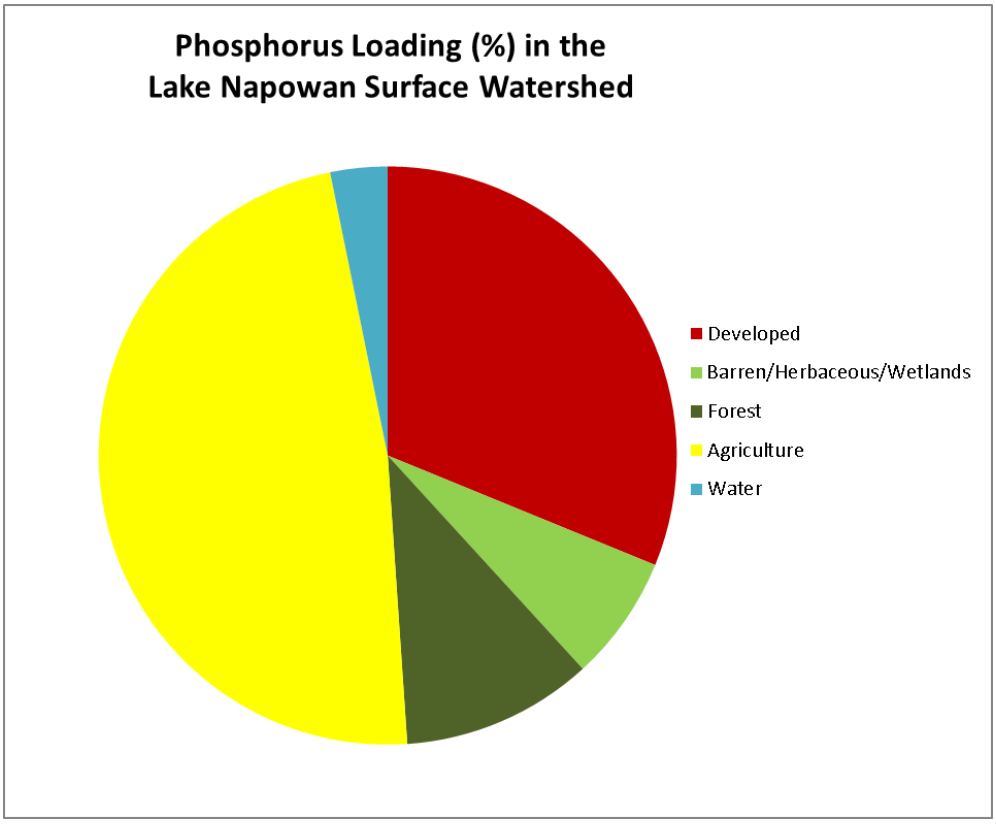


FIGURE 8. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE LAKE NAPOWAN WATERSHED.

TABLE 4. MODELING DATA USED TO ESTIMATE PHOSPHORUS INPUTS FROM LAND USES IN THE LAKE NAPOWAN WATERSHED (LOW AND MOST LIKELY COEFFICIENTS USED TO CALCULATE RANGE IN POUNDS).

Lake Napowan Land Use	Phosphorus Export Coefficient (lbs/acre-yr)	Land Use Area Within the Watershed		Estimated Phosphorus Load	
		Acres	Percent	Pounds	Percent
Water	0.1	177	**14**	5-31	**3**
Developed	0.13	339	**27**	45-152	**31**
Barren/Herbaceous/Wetland	0.09	114	**9**	10-31	**7**
Forest	0.04	349	**28**	16-29	**11**
Cultivated Agriculture	0.45	260	**21**	70-185	**48**
*Values are not exact due to rounding and conversion.					

Although a fair amount of phosphorus comes off of the landscape, so far the moderately hard water in Lake Napowan has helped to buffer nutrient impacts from the watershed as evidenced by low measures of algae (chlorophyll *a*). The moderately hard water has a limited buffering capacity, so measures should be taken to reduce near shore and watershed-scale impacts to the lake. Atrazine, an agricultural herbicide, is likely traveling in the groundwater that flows into the lake.

AQUATIC PLANTS

(Based on contributions from Golden Sands Resource Conservation & Development Council, Inc., 2014)

Aquatic plants play important roles in a lake's ecosystem. They provide habitat for the fishery and other aquatic organisms, stabilize the sediment, reduce erosion, buffer temperature changes and waves, and infuse oxygen into the water. Aquatic plants near shore provide food, shelter and nesting material for shoreland mammals, shorebirds and waterfowl. It is not unusual for otters, beavers, muskrats and deer to be seen along a shoreline in their search for food or nesting material. The aquatic plants that attract the animals to these areas contribute to the beauty of the shoreland and lake.

The rapid and sometimes dominant growth of aquatic invasive plants, such as Eurasian watermilfoil (EWM), may reduce the recreational value of a lake. Aquatic invasive plants may also outcompete and cause a decline in native vegetation, which degrades habitat diversity and can alter the aquatic ecosystem. A healthy native aquatic plant population can help to guard against an exploding population of EWM. Disturbing the native community though raking or use of chemicals can provide ideal substrate for EWM and other invasives to become established.

An aquatic plant survey of Lake Napowan was conducted by Golden Sands Resource Conservation & Development Council, Inc. in August 2013. Ninety-six percent (219 of 227) of the sites visited had vegetative growth. The greatest depth at which aquatic plant growth was found was 19.7 feet. Twenty species of aquatic plants were found in Lake Napowan, with an additional five species observed visually (Table 5). Figure 9 shows the number the number of species that were identified at each sampling site. The twenty-five total species observed within Lake Napowan is above average compared with the other 31 lakes in the Waushara County study.

The dominant plant species found in Lake Napowan was coontail (*Ceratophyllum demersum*), followed by southern naiad (*Nijas guadalupensis*) and common waterweed (*Elodea canadensis*). Coontail offers an important food source to a wide range of waterfowl species. A number of invertebrate and fish species use the bushy stems and stiff whorls of the leaves of the coontail plant as habitat, especially in the winter when other aquatic plants have died back. Southern naiad also provides food to waterfowl, and both shelter and food to fish. Common waterweed is a food source for muskrats and waterfowl, and also provides shelter and grazing opportunities for fish (Borman et al., 2001).

The Floristic Quality Index (FQI) evaluates how closely a plant community is to undisturbed conditions. Each plant is assigned a coefficient of conservatism value (C-value) that reflects its sensitivity to disturbance, and these numbers are used to calculate the FQI. C-values range from 0 to 10: the lower the number, the more tolerant the plant is of disturbance. Having more plants with low C-values than high C-values is an indicator of disturbance, as the lower C-value plants better tolerate stresses caused by disturbance. A C-value of 0 is assigned to exotic species. The FQI for Lake Napowan was 26.6, which was slightly above average for the lakes in the Waushara County study.

In Lake Napowan, C-values ranged from 0 to 8 (Table 5). Three of the twenty-five species found in Lake Napowan had a C-value of 8, indicating good health in the aquatic plant community. The species with the highest frequency of occurrence within vegetated areas was coontail, with a C-value of 3. One invasive aquatic plant species was sampled, EWM, with a C-value of 0.

The Simpson Diversity Index (SDI) quantifies biodiversity based on a formula that uses the number of species surveyed and the number of individuals per site. The SDI uses a decimal scale from 0 to 1. Values closer to one represent higher amounts of biodiversity. The SDI of Lake Napowan for the 2013 survey was 0.92. This represents above average biodiversity when compared to other lakes in the Waushara County study.

TABLE 5. LIST OF AQUATIC PLANT SPECIES IDENTIFIED IN THE 2013 AQUATIC PLANT SURVEY OF LAKE NAPOWAN.

Scientific name	Common name	Sampled	Visual	C-value
Brasenia schreberi	watershield	x	x	6
Ceratophyllum demersum	coontail	x	x	3
Chara spp.	muskgrass	x	x	7
Elodea canadensis	common waterweed	x	x	3
Myriophyllum spicatum	Eurasian watermilfoil	x	x	0
Najas flexilis	slender naiad	x	x	6
Najas guadalupensis	southern naiad	x	x	8
Nelumbo lutea	American lotus	x		7
Nitella spp.	stoneworts	x		7
Nuphar variegata	bullhead pond lily		x	6
Nymphaea odorata	white water lily	x	x	6
Polygonum amphibium	amphibious smartweed		x	6
Potamogeton amplifolius	large-leaf pondweed	x	x	7
Potamogeton friesii	Fries' pondweed	x		8
Potamogeton gramineus	variable pondweed	x	x	7
Potamogeton illinoensis	Illinois pondweed	x	x	6
Potamogeton natans	floating-leaf pondweed	x	x	5
Potamogeton praelongus	white-stem pondweed	x	x	8
Potamogeton pusillus	small pondweed	x	x	7
Potamogeton zosteriformis	flat-stem pondweed	x	x	6
Schoenoplectus acutus	hard-stem bulrush		x	6
Schoenoplectus pungens	three-square bulrush		x	5
Schoenoplectus tabernaemontani	soft-stem bulrush		x	4
Sagittaria spp.	arrowheads	x	x	5
Vallisneria americana	water celery	x	x	6
	freshwater sponges	x		-

Invasive species are present in Lake Napowan. EWM is present in low to moderate abundance throughout the lake. Depending upon the extent of growth, EWM may grow in dense beds that could potentially damage boat motors, make areas less navigable, stunt or alter the fishery, create problems with dissolved oxygen, and affect activities like fishing and swimming. This plant can produce a viable seed; however, its primary mode of reproduction and spread is fragmentation. A one-inch fragment is enough to start a new plant, making EWM very successful at reproducing.

Curly-leaf pondweed (Potamogetan crispus), CLP, was not found during the survey; however, it was reported in 1994 and has not been confirmed with a voucher specimen. A decaying turion was also found during a July survey. Because the 2013 survey took place in August, results for CLP may not be representative of the population due to the unique life cycle of the plant. CLP typically dies off in late June, releasing phosphorus from its plant tissues into the water. The timing of the die off can be problematic by fueling filamentous algae blooms. The CLP turions, or winter buds, establish themselves in a suitable substrate shortly after the plants die back. When conditions are right in autumn, the turions will sprout and exist in a dormant state under the ice. The plants then resume growth shortly after ice out; this unique life cycle gives it a head start and a competitive advantage over other aquatic plants.

Aquatic plants play another critical role in the lake's ecosystem by using nutrients that would otherwise be available to algae. Any management activities should be planned to minimize the disturbance of native species in the water and on shore in order to maintain the balance between aquatic plants and algae. In addition, care should be taken to minimize raking the lake bed and pulling plants, since disturbing these valuable open spaces may allow invasive plants such as EWM to establish.

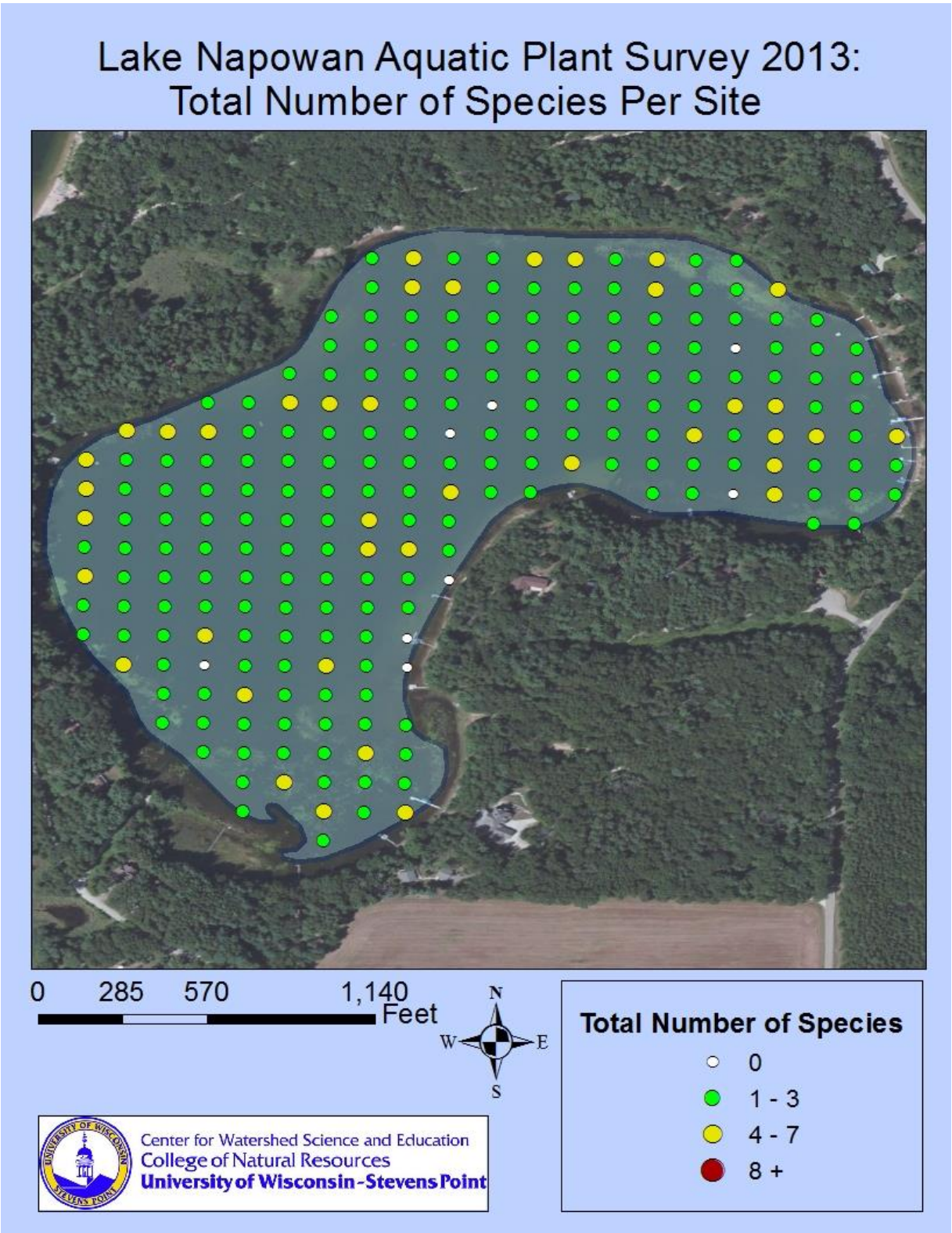


FIGURE 9. NUMBER OF AQUATIC PLANT SPECIES OBSERVED AT EACH SAMPLE SITE IN LAKE NAPOWAN, AUGUST 2013.

SHORELANDS

Shoreland vegetation is critical to a healthy lake's ecosystem. It provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and many small and large mammals. It also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs, and trees which extend at least 35 feet landward from the water's edge.

To better understand the health of the Waushara County lakes, shorelands were evaluated by the Center for Land Use Education and Waushara County as a part of the Waushara County Lakes Study. The survey inventoried the type and extent of shoreland vegetation. Disturbed areas with erosion, rip-rap, barren ground, sea walls, structures and docks were also inventoried.

A scoring system was developed for the collected data to provide a more holistic assessment. Areas that are healthy will need strategies to keep them healthy, and areas with potential problem areas and where management and conservation may be warranted may need a different set of strategies for improvement. The scoring system is based on the presence/absence and abundance of shoreline features, as well as their proximities to the water's edge. Values were tallied for each shoreline category and then summed to produce an overall score. Larger scores denote a healthier shoreline with good land management practices. These are areas where protection and/or conservation should be targeted. On the other hand, lower scores signify an ecologically unhealthy shoreline. These are areas where management and/or mitigation practices may be desirable for improving water quality.

The summary of scores for shorelands around Lake Napowan is displayed in Figure 10. The shorelands were color-coded to show their overall health based on natural and physical characteristics. Blue shorelands identify healthy shorelands with sufficient vegetation and few human disturbances. Red shorelands indicate locations where changes in management or mitigation may be warranted. Large stretches of Lake Napowan's shorelands are in good to moderately-good shape, but a few portions have challenges that should be addressed. One segment along the northeastern shore was ranked as poor. A summary of shoreland disturbances is displayed in Table 6. For a more complete understanding of the ranking, an interactive map showing results of the shoreland surveys can be found on Waushara County's website at http://gis.co.waushara.wi.us/ShorelineViewer/.

TABLE 6. DISTURBANCES WITHIN 15 FEET OF SHORE AROUND LAKE NAPOWAN, 2011.

Disturbance	Length of Shore	
	Feet	Percent
Artificial beach	2007	27
Barren, bare dirt	0	0
Boat landing	53	1
Dock/pier at water	5648	76
Gully erosion	0	0
Undercut banks erosion	0	0
Mowed lawn	1264	17
Rip-rap	755	10
Seawall	1633	22



FIGURE 10. OVERALL SHORELAND HEALTH AROUND LAKE NAPOWAN, 2011.

CONCLUSIONS AND RECOMMENDATIONS

In general, Lake Napowan has good water quality; however, a few water quality measurements such as chloride, sodium, and atrazine indicate that land use management practices in the watershed are influencing the water quality in Lake Napowan. Although sources of phosphorus from agriculture and developed land exist in the Lake Napowan watershed, so far the moderately hard water (from calcium in the groundwater) in Lake Napowan has helped to buffer the additional nutrients. This is evidenced by lower measures of algae.

- The hard water has limited capacity to buffer phosphorus, so measures should be taken to reduce near shore and watershed-wide impacts to Napowan Lake.
- Atrazine was elevated in the lake water.
    - This chemical enters the lake via groundwater.
    - Low concentrations of atrazine have been shown to impact frogs and some fish species.
    - Private well owners should consider testing their well water for atrazine as there are health concerns associated with consuming or inhaling this water. The source is from application on corn cropland.
- Over-application of chemicals and nutrients should be avoided. Landowners in the watershed should be made aware of their connection to Lake Napowan and should work to reduce their impacts through the implementation of water-quality based best management practices.
- The Waushara County Land Conservation Department and Natural Resources Conservation Service (NRCS) have professional staff available to assist landowners interested in learning how they can improve water quality through changes in land management practices.

Large stretches of shorelands around Lake Napowan are considered healthy. Intermittent parts of the shoreland could be improved and several stretches were ranked as poor. Sedimentation and excessive nutrient inputs accelerate algae and aquatic plant growth in the lake. Some erosion and sedimentation occur naturally in the watershed, but they are commonly increased by shoreline disturbance and fertilizer applications.

- Strategies should be developed to ensure that healthy shorelands remain intact and efforts should be made to improve shorelands that have disturbance. Depending upon the source of disturbance, erosion should be controlled, vegetation should be restored, and/or excess runoff should be minimized.
- Dissemination of relevant information to property owners is always a recommended first step towards maintaining healthy shorelands.
- The Waushara County Land Conservation Department has professional staff available to assist shoreland property owners interested in learning how they can improve water quality through changes in land management practices.

Lake Napowan has a moderately diverse aquatic plant community. The lake has designated wake speed hours between 10 AM and 4:30 PM. Boat wakes can create unstable conditions for aquatic plants, and in some cases may decrease the possibility for the presence of rare species that may be less tolerant of disturbance.

Two invasive species of aquatic plants have been identified in Lake Napowan.

- Curly leaf pondweed (*Potamogetan crispus*), CLP, can become invasive and may contribute to nuisance algae blooms throughout the summer. CLP was not found in the August 2013 aquatic plant survey, but it should be monitored annually in early June. If the beds continue to expand, management should be considered.
- Eurasian watermilfoil (EWM) accounts for a moderate portion of the plant biomass in Lake Napowan. EWM can create dense beds which can stall or burn up boat motors, make areas non-navigable, and prevent activities like swimming and fishing. This plant can produce viable seed; however, its primary mode of spread is fragmentation. Just a small fragment of the stem is enough to start a new plant.
- Since populations of EWM are present, an aquatic plant management (APM) plan should be developed. The APM should identify recommended measures to manage EWM in Lake Napowan.
- The amount of disturbed lake bed from raking or pulling of plants should be minimized, since these open spaces are simply "open real estate" for aquatic invasive plants to establish.
- Boats and trailers that have visited other lakes can be a primary vector for the transport of aquatic invasive species (AIS). Volunteer boat inspectors at the boat landing, trained through the Clean Boats Clean Waters (CBCW) program, can help prevent new AIS introductions. The lack of intensive high-speed recreational boating helps to preserve the integrity of Lake Napowan by reducing disturbance to the lakebed. Disturbed conditions often encourage the colonization of AIS.
- Monitoring for AIS should be conducted routinely throughout the lake by either trained citizen volunteers or paid personnel.

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GLOSSARY OF TERMS

Algae: One-celled (phytoplankton) or multicellular plants either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

Atrazine: A commonly used herbicide. Transports to lakes and rivers by groundwater or runoff. Has been shown to have toxic effects on amphibians.

Blue-Green Algae: Algae that are often associated with problem blooms in lakes. Some produce chemicals toxic to other organisms, including humans. They often form floating scum as they die. Many can fix nitrogen (N2) from the air to provide their own nutrient.

Calcium (Ca++): The most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed. Reported as milligrams per liter (mg/1) as calcium carbonate (CaCO3), or milligrams per liter as calcium ion (Ca++).

Chloride (Cl-): The chloride ion (Cl-) in lake water is commonly considered an indicator of human activity. Agricultural chemicals, human and animal wastes, and road salt are the major sources of chloride in lake water.

Chlorophyll *a*: Green pigment present in all plant life and necessary for photosynthesis. The amount present in lake water depends on the amount of algae, and is therefore used as a common indicator of algae and water quality.

Clarity: See "Secchi disk."

Color: Color affects light penetration and therefore the depth at which plants can grow. A yellow-brown natural color is associated with lakes or rivers receiving wetland drainage. Measured in color units that relate to a standard. The average color value for Wisconsin lakes is 39 units, with the color of state lakes ranging from zero to 320 units.

Concentration units: Express the amount of a chemical dissolved in water. The most common ways chemical data is expressed is in milligrams per liter (mg/l) and micrograms per liter (ug/l). One milligram per liter is equal to one part per million (ppm). To convert micrograms per liter (ug/l) to milligrams per liter (mg/l), divide by 1000 (e.g. 30 ug/l = 0.03 mg/1). To convert milligrams per liter (mg/l) to micrograms per liter (ug/l), multiply by 1000 (e.g. 0.5 mg/l = 500 ug/l).

Cyanobacteria: See "Blue-Green Algae."

Dissolved oxygen: The amount of oxygen dissolved or carried in the water. Essential for a healthy aquatic ecosystem in Wisconsin lakes.

Drainage basin: The total land area that drains runoff towards a lake.

Drainage lakes: Lakes fed primarily by streams and with outlets into streams or rivers. They are more subject to surface runoff problems, but generally have shorter residence times than seepage lakes.

Emergent: A plant rooted in shallow water and having most of its vegetative growth above water.

Eutrophication: The process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Groundwater drainage lake: Often referred to as a spring-fed lake, it has large amounts of groundwater as its source and a surface outlet. Areas of high groundwater inflow may be visible as springs or sand boils. Groundwater drainage lakes often have intermediate retention times with water quality dependent on groundwater quality.

Hardness: The quantity of multivalent cations (cations with more than one +), primarily calcium (Ca++) and magnesium (Mg++) in the water expressed as milligrams per liter of CaCO3. Amount of hardness relates to the presence of soluble minerals, especially limestone or dolomite, in the lake watershed.

Intermittent: Coming and going at intervals, not continuous.

Macrophytes: See "Rooted aquatic plants."

Marl: White to gray accumulation on lake bottoms caused by precipitation of calcium carbonate (CaCO3) in hard water lakes. Marl may contain many snail and clam shells. While it gradually fills in lakes, marl also precipitates phosphorus, resulting in low algae populations and good water clarity. In the past, marl was recovered and used to lime agricultural fields.

Mesotrophic: A lake with an intermediate level of productivity. Commonly clear water lakes and ponds with beds of submerged aquatic plants and mediums levels of nutrients. See also "eutrophication".

Nitrate (NO3-): An inorganic form of nitrogen important for plant growth. Nitrate often contaminates groundwater when water originates from manure, fertilized fields, lawns or septic systems. In drinking water, high levels (over 10 mg/L) are dangerous to infants and expectant mothers. A concentration of nitrate-nitrogen (NO3-N) plus ammonium-nitrogen (NH4-N) of 0.3 mg/L in spring will support summer algae blooms if enough phosphorus is present.

Oligotrophic: Lakes with low productivity, the result of low nutrients. Often these lakes have very clear waters with lots of oxygen and little vegetative growth. See also "eutrophication".

Overturn: Fall cooling and spring warming of surface water increases density, and gradually makes lake temperatures and density uniform from top to bottom. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. Common in many lakes in Wisconsin.

Phosphorus: Key nutrient influencing plant growth in more than 80% of Wisconsin lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Rooted aquatic plants (macrophytes): Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects and provide food for many aquatic and terrestrial animals. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

Secchi disk: An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration).

Sedimentation: Materials that are deposited after settling out of the water.

Stratification: The layering of water due to differences in density. As water warms during the summer, it remains near the surface while colder water remains near the bottom. Wind mixing determines the thickness of the warm surface water layer (epilimnion), which usually extends to a depth of about 20 feet. The narrow transition zone between the epilimnion and cold bottom water (hypolimnion) is called the metalimnion. Common in many deeper lakes in Wisconsin.

Watershed: See "Drainage basin."